3D Simulations of the Local Bubble

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Abstract. We have performed high resolution 3D simulations of the Local Bubble (with 1.25 pc finest resolution) in a *realistic background ISM*, jointly with the dynamical evolution of the neighbouring Loop I superbubble. We can reproduce (i) the size of the bubbles (in contrast to similarity solutions), (ii) the interaction shell with Loop I, discovered with ROSAT, (iii) predict the merging of the two bubbles in about 3 Myr, when the interaction shell starts to fragment, and, (iv) the generation of blobs like the Local Cloud as a consequence of a dynamical instability.

Keywords: ISM: general, superbubbles, Local Bubble

1. Introduction

The Local Bubble (LB) is a cavity, elongated towards the Galactic North Pole, with an average extension of about 100 pc, copiously radiating in soft X-rays. There exist a number of discrepancies between observations and modelling that have all been outlined in a recent panel discussion (Breitschwerdt & Cox 2004). Most models proceed from a multi-supernova origin of the LB (cf. Berghöfer & Breitschwerdt 2002 for possible supernova (SN) progenitors), in which the LB is the result of successive SN explosions, although part of the soft X-ray emission could be of heliospheric origin, generated by charge exchange reactions between solar wind ions and heliospheric plasma.

2. Results and Discussion

We use a 3D Godunov type parallelized AMR hydrocode to track small scale structures down to 1.25 pc, where necessary (for details see Avillez 2000). According to Berghöfer & Breitschwerdt (2002) 20 stars of Pleiades subgroup B1 with masses between 10 and 20 $M_\odot$ were moving through the LB within the last 14 Myr, exploding after their main sequence life time, $\tau_{\rm ms}$, along a path crossing $x = 175$, $y = 400$ pc (see Fig. 1), thus generating the Local Cavity into which

Left panel: breitsch_fig1a Right panel: breitsch_fig1b

Figure 1. Left: Temperature map (Galactic plane cut) of a 3D LB simulation at present (i.e. 14.4 Myr after first explosion) with the LB centered at (175, 400) pc and Loop I 200 pc to the right. *Right:* Same, but at $t = 17$ Myrs, showing fragmentation of the interaction shell and formation of cloudlets by hydrodynamic instabilities.

the LB expands. The Galactic SN rate has been used for the setup of *other SNe* in the background disk. First we derive analytic similarity solutions, taking an initial mass function for Galactic OB associations with powerlaw index $\Gamma = -1.1$, and using $\tau_{\rm ms} = 3\,10^7\,(m/[10{\rm M}_\odot])^{-\alpha}$ yr (Stothers 1972), with $\alpha = 1.6$, for stars within the mass range $7\,{\rm M}_\odot \leq m \leq 30\,{\rm M}_\odot$. The mechanical energy input rate (see Berghöfer & Breitschwerdt 2002) then is $L_{\rm SB} = L_0\,t_7^{\delta}$, where $L_0 = 4.085 \times 10^{37}\,{\rm erg/s}$, $\delta = -(\Gamma/\alpha + 1) = -0.3125$ and $t_7 = t/10^7$ yr. Modifying suitably the similarity solutions of McCray & Kafatos (1987), we obtain $R_b = At^{\mu} = 251\,(2 \times 10^{-24}{\rm g/cm^3}/\rho_0)^{1/5}\,t_7^{\mu}$ pc with $\mu = (2-\Gamma/\alpha)/5 = 0.5375$. Note, that our value of μ is between the canonical value of 0.4 for a Sedov-type solution and 0.6 for a wind type solution, due to the declining energy input rate with time. If we now try to match a present day average radius of the LB of even 146 pc at time $t_{\rm dyn} = 14.4$ Myr, we need a constant ambient density of $n_0 \simeq 40\,{\rm cm}^{-3}$, a value way above the average ISM density. Comparison with our excellently matching numerical results shows, however, that this discrepancy must be due to mass loading, and turbulence in a SN disturbed *background* medium.

References

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